

Changing bodies changes minds: owning another body affects social cognition

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Abstract

1 Research on stereotypes demonstrates how *existing* prejudice affects the way we process
2 outgroups. Recent studies have considered whether it is possible to *change* our implicit social bias
3 by experimentally changing the relation between the self and outgroups. In a number of
4 experimental studies, participants have been exposed to bodily illusions that induced ownership
5 over a body different to their own with respect to gender, age or race. Ownership of an outgroup
6 body has been found to be associated with a significant reduction in implicit biases against that
7 outgroup. We propose that these changes occur via a process of self-association that first takes place
8 in the physical, bodily domain as an increase in perceived physical similarity between self and
9 outgroup member. This self-association then extends to the conceptual domain, leading to a
10 generalization of positive self-like associations to the outgroup.

11 **Keywords:** *body ownership, racial biases, implicit attitudes, social cognition, bodily illusions,*
12 *immersive virtual reality*

13

14 **Highlights**

- 15 ▪ Multisensory correlations can induce illusory ownership of another person's body.
- 16 ▪ Ownership can thus be induced over a body of a different race, age, or gender.
- 17 ▪ Incorporating a body belonging to a social outgroup changes implicit social biases.
- 18 ▪ The multisensory experience of the body underpins higher-level social attitudes.

19 **Body representations of self and other.**

20 Embodied accounts of social cognition suggest that the way in which we perceive others'
21 bodies in relation to our own plays a crucial role in sociocognitive processing [1-7]. The perception
22 of bodily states in others can activate similar bodily states in the self, and this is taken as evidence
23 that our representations of our own bodies and those of others can partially overlap. These shared
24 body representations are thought to form the fundamental basis of empathy and our understanding
25 of others' emotions and actions. Interestingly, the activation of shared body representations is
26 modulated by whether the person being observed is an ingroup or an outgroup member. For
27 example, when we observe an individual of a different race to ourselves experiencing a specific
28 bodily state, such as touch or pain, we show a reduced sharing of that bodily state. Furthermore, this
29 reduction is modulated by our implicit social attitudes towards that racial group; the more
30 negatively biased we are against members of that race, the less overlap between our representations
31 of their bodies and our own [see below; 3-4,8].

32 Until recently, research in this area has focused on how existing social bias and prejudice
33 affect the way we process outgroup members [3-6], rather than investigating the potential
34 malleability of our ingroup/outgroup classifications. A series of recent studies have successfully
35 filled this gap [9-14] by asking whether and how it is possible to change implicit social attitudes
36 towards outgroups [15] by experimentally increasing the sharing of body representations [16].
37 Taken together, the findings show that changes in the mental representation of one's own body
38 affect the perceived similarity between one's own body and that of an outgroup, resulting in
39 significant changes in implicit biases. We here present a possible mechanism underlying these
40 changes, which has far-reaching implications for our understanding of the development and
41 malleability of social attitudes, and the crucial role of basic body representations in these processes.

42 **Racial Biases in Brain, Behaviour and the Body**

43 A rapidly growing literature suggests that the body is central to our understanding of others.
44 Neurocognitive studies into the ‘mirror neuron system’ have shown that we activate similar brain
45 regions both when we observe a bodily state in others and when we experience that bodily state
46 ourselves [17], reflecting an overlap between self and other bodily representations in the brain [18].
47 Evidence now suggests that this bodily resonance (see Glossary) can afford us a unique, first-person
48 understanding of the experiences of others and is central to a number of social processes [7]
49 including intention understanding [19], empathy [20], and emotion recognition [21]. Importantly,
50 recent studies have revealed that social group categorisation, such as that based on racial group
51 membership, can have a strong impact on the extent to which we resonate with others’ bodily states.

52 Racial group membership is a salient distinguishing factor between individuals, and has long
53 been known to strongly impact human social behaviours and attitudes. For example, we tend to
54 show implicit biases towards members of our own race and against those of other races, even when
55 we don’t hold any explicitly biased attitudes. These implicit racial biases can be measured
56 behaviourally using an implicit association task (IAT: See Glossary [15]), but also can be seen at
57 the neural level in the form of distinct patterns of brain activity [2]. Intriguingly, bodily resonance is
58 modulated by whether the other person being observed is a member of a racial ingroup or outgroup
59 [3-8]. For example, viewing a face being touched enhances the perception of touch on one’s own
60 face, but this effect, known as the Visual Remapping of Touch, is not present when the observed
61 face belongs to a racial outgroup member [5]. In the motor domain, participants show reduced
62 vicarious activation of the motor cortex when observing actions performed by a racial outgroup
63 member as compared to an ingroup member [4,8], and show decreased neural and motor responses
64 when viewing racial outgroup members in pain [3,6]. Furthermore, this diminished neural
65 resonance with the racial outgroup has been found to directly correlate with participants’ negative
66 implicit racial biases [3].

67 Until recently, research in this area has focussed on how bodily resonance is affected by
68 existing racial attitudes. Could this relationship, in fact, be bidirectional? In other words, could

69 existing racial attitudes be modulated by the experimental manipulation of shared body
70 representations? A series of recent studies has employed a range of multisensory methods to
71 manipulate body ownership and has revealed striking effects on implicit racial attitudes.

72 **From body ownership to social cognition: Constraints and consequences**

73 Over the last twenty years, advances in experimental psychology, cognitive neuroscience
74 and virtual reality have allowed scientists to experiment with a fundamental element of self-
75 awareness, the sense of body ownership (see Glossary), using a range of bodily illusions, such as
76 the Rubber Hand Illusion [22], the Full Body Illusion [23-25] and the Enfacement Illusion [26] (see
77 Box 1 for descriptions). These successful manipulations aptly demonstrated the malleability of the
78 mental representation of one's body and identity.

79 Having established the behavioural and neural correlates of these multisensory-induced
80 changes in body ownership, attention has turned towards the potential social constraints, as well as
81 the social consequences, of such changes. Importantly, illusions of body ownership were revealed to
82 be surprisingly impervious to social and perceptual distinctions. Several studies, using a variety of
83 methods, successfully induced a sense of body ownership over bodies of different race- [9,10,12-
84 14,27, 28, 29], age- [11], size- [11,30,31,32] and gender-groups [25]. Furthermore, in the case
85 where the different body depicted an outgroup person, the acquired ownership did not depend on
86 pre-existing levels of implicit outgroup bias; participants experienced ownership over another's
87 body regardless of their levels of negative implicit attitudes towards the other's social group [13].
88 This provides an interesting contrast with the findings already discussed, which show that shared
89 body representations, in the absence of experimental manipulations that prime the self-relevance of
90 the observed body, are indeed greatly influenced by factors such as racial attitudes. However, the
91 manipulations used to induce bodily illusions involve highly salient multisensory cues which are
92 strongly predictive of body ownership, and thus may override top-down modulations by social
93 attitudes [9-13]. Conversely, in the absence of these powerful multisensory cues, the effects of
94 social attitudes on bodily resonance with others may emerge.

95 Despite being relatively impervious to social factors, the experimental modulation of body
96 ownership was found to have a number of intriguing effects on social cognition. After synchronous
97 multisensory stimulation on the face (see Enfacement Illusion, Box 1), participants rated the other's
98 face as more attractive, more physically similar to their own, and they were also more likely to
99 conform to the other's opinions [33]. Effects were also seen in the emotional domain; the
100 enfacement illusion improved recognition of the other's emotions, with a specific increase in
101 sensitivity to fearful facial expressions [34].

102 **Changing your body changes your mind**

103 Although changes in body ownership were found to affect social processing of 'embodied'
104 individuals, the question of whether these changes could affect implicit biases against outgroups
105 remained unanswered. In the first study to test this [9], participants' implicit racial attitudes were
106 measured before and after they experienced a rubber hand illusion with a hand of a different racial
107 group (see Fig.1). To begin, light-skinned Caucasian participants completed a skin-color IAT to
108 assess their implicit attitudes towards individuals with dark skin. In a separate session, synchronous
109 multisensory stimulation was used to induce the feeling that a dark-skinned hand belonged to them,
110 before their implicit attitudes were measured for a second time. As shown previously [13],
111 participants experienced the other-race hand as their own and body ownership occurred regardless
112 of their implicit attitudes towards that race. Importantly, participants showed a significant decrease
113 in negative implicit attitudes towards dark skin, which correlated with the strength of ownership
114 experienced over the other-race hand. The more intense the participants' illusion of ownership over
115 the dark-skinned rubber hand, the more positive their implicit racial attitudes became.

116 In a similar way, using an immersive virtual reality set-up [10], embodiment of light-
117 skinned people in a dark-skinned virtual body reduced their implicit racial bias as measured by a
118 racial IAT. To control for the effects of mere perceptual difference between the body of the avatar
119 and participants' actual bodies, in another condition participants embodied a purple-skinned body,
120 but this condition did not produce any changes in racial bias (see Fig.2) even though the subjective

121 illusion of body ownership was strong and not significantly different from embodiment of the light-
122 or dark-skinned bodies.

123 Importantly, such changes in body ownership to incorporate an outgroup body also increase
124 ‘bodily resonance’ with that outgroup. As previously discussed, our perceptual and neural
125 resonance with others’ bodily experiences is significantly reduced when observing an outgroup
126 member [3-6,8]. An example of this can be seen in the Visual Remapping of Touch effect, a
127 phenomenon whereby our tactile sensitivity is enhanced when observing another person being
128 touched. This effect, thought to be evidence of somatosensory resonance with others, is
129 significantly reduced when the observed individual is a member of a racial or political outgroup [5].
130 In a recent study, an Enfacement Illusion was rapidly induced by exposing participants to two
131 minutes of multisensory stimulation whilst viewing an out-group member’s face [14]. Immediately
132 afterwards, participants’ tactile sensitivity was measured whilst they observed the out-group
133 member’s face being touched. Results showed that the experience of body ownership over the out-
134 group member’s face had increased the Visual Remapping of Touch effect up to the level normally
135 associated with a same-race individual.

136 A further study investigated implicit attitudes towards age [11] using an immersive virtual
137 reality setup similar to that employed in previous studies [10]. Embodying an avatar representing a
138 4-year-old child resulted in a bias towards associating the self with child-like compared to adult-like
139 categorizations, as measured using an IAT. This study was notable because it demonstrated a role of
140 the self-association in attitude change, whereas previous research [9,10] had investigated more
141 generic positive or negative associations with the embodied social group. This can provide us with
142 the beginnings of a mechanism to explain how exactly ‘changing your body’ is able to also ‘change
143 your mind’.

144 **Illusions of self-resemblance may cause a generalisation of self-like associations to an**
145 **outgroup**

146 How can a change in the perception of a purely bodily aspect of the self ultimately alter not only
147 associations with a higher-level concept of the self [11], but also generalize to the affective and
148 social processing of others? We argue that these changes occur via a process of self-association,
149 first in the physical, bodily domain as an increase in perceived physical similarity between self and
150 outgroup member, and then in the conceptual domain, leading to a generalization of positive self-
151 like associations to the outgroup.

152 The first relevant finding to support our argument is that experimentally induced modulations of
153 body ownership enhance perceived physical similarity between self and other. For example, after
154 the rubber hand illusion, participants rated the rubber hand as more physically similar to their own
155 [26]. In a more objective quantification of a comparable effect, participants accepted morphed
156 photos of faces with a higher percentage of the other as depicting themselves after experiencing an
157 enfacement illusion, suggesting that the participants' stored representations of their own faces were
158 altered to incorporate aspects of the other person [26,35,36].

159 We suggest that this increased perceptual similarity between oneself and an outgroup member
160 leads to a new association being formed between the self-concept and that outgroup. For this to
161 occur, two processes are necessary. First, the perceptual self-similarity of the outgroup must
162 activate the self-concept. We know that even subliminal exposure to images of one's own body
163 automatically activates positive self-associations [37,38] and thus we argue that perceptions of self-
164 similar bodies may activate self-associations in the same way. The second required step is for the
165 positive evaluations associated with the self-concept to be generalized to the outgroup, by virtue of
166 their perceptual similarity to the self. In support of this, the classical conditioning literature has long
167 posited that associative learning of likes and dislikes are based on perceptual similarity, and that this
168 can occur outside of awareness [39,40]. This process of evaluative conditioning has been shown to
169 extend to social stimuli; individuals rapidly and unintentionally generalize affective processing to
170 individuals who look physically similar [41,42].

171 We propose that, because of a newly established physical similarity between self and outgroup,
172 the conceptual representations of self and outgroup also become linked. Via a process of evaluative
173 generalization, the positive evaluations associated with the self-concept now extend to the
174 embodied outgroup. This results in the outgroup not only being associated with the self-concept, as
175 already shown by [11], but also with positive concepts more generally, as shown by [9,10]. This
176 mechanism can be thought of as maintaining consistency between the multifaceted aspects of self
177 (personality, attitudes and behaviors) and the body representation following the updates of the sense
178 of body ownership (see Box 2).

179 The mechanism proposed here appeals to basic, well-established processes from the associative
180 learning literature to provide a clear and plausible explanation of current findings. The novel step
181 we have taken is to pair an associative account with what we know about the perceived physical
182 similarity elicited by bodily illusions. By appealing to a multidimensional self-representation, in
183 which both bodily and conceptual aspects of the self are bound in a coherent, supramodal construct,
184 we can bridge the gap between the perceptual, bodily representations involved in body ownership,
185 and the evaluative, conceptual representations involved in implicit social attitudes. The resulting
186 mechanism provides us with a coherent account of how changes in body ownership can close this
187 gap in order to affect higher-level social processes.

188 **Concluding Remarks**

189 Overall, an intriguing and consistent pattern of results has emerged from independent research
190 groups, whereby changes in the experience of ownership over an outgroup body of different race
191 results in significant reductions of the levels of implicit bias against that outgroup . Furthermore,
192 similar changes are elicited in measures of somatosensory remapping [14] that reflect levels of body
193 resonance between people. Taken together, these findings suggest that changes in the perceived
194 similarity between self and others, caused by shared multisensory experiences, might ‘bridge the
195 gap’ between the basic, perceptual representation of bodies, and the complex social mechanisms
196 underlying much of our everyday social interaction.

197 A key challenge for future work is to elucidate the neural mechanisms involved in these
198 changes. The networks involved in implicit racial bias are already known [2], and appear to serve
199 two related yet distinct functions. The first function, likely to be subserved by the amygdala,
200 generates a rapid, automatic affective reaction to other-race stimuli, and the second, subserved by
201 the dorsolateral prefrontal cortex and anterior cingulate cortex, controls and regulates the expression
202 of this affective reaction according to explicitly desired behaviours. Thus, an investigation of the
203 neural mechanisms of our findings will allow us to clearly elucidate exactly which process is being
204 altered; do the changes in body ownership alter the initial affective processing of the racial
205 outgroup, or instead alter the way this affective reaction is detected, controlled and expressed?

206 A neural investigation of the effects of ‘changing race’ will also reveal important information
207 regarding its effects on bodily resonance. Initial behavioural evidence has suggested that induced
208 changes in body ownership can increase somatosensory resonance when observing a different-race
209 individual being touched [14]. An important next step would be to investigate if this increased
210 resonance extends to other domains, e.g., the motor domain, where it could have important
211 consequences for key social processes [7]. We propose that changes in perceived interpersonal
212 similarity play a causal role in this mechanism, and it is now timely to elucidate how exactly this
213 interpersonal bodily similarity may modulate activity in the ‘mirror system’.

214 These recent findings also lead us to new insights into how implicit social biases are formed and
215 maintained. Previously, implicit racial biases have been considered relatively difficult to change
216 [43]. Earlier attempts to alter these racial biases have tended to involve lengthy training
217 programmes and conscious interventions [e.g. 44]. In contrast, the research we have reviewed here
218 has revealed an exciting new mechanism by which implicit social biases can be modulated ‘from
219 the body upwards’. We propose a potential cognitive underpinning of these changes, from body
220 ownership to social cognition, which appeals to associative learning and predictive coding to
221 provide us not only with a rich theoretical framework in which the current data can be understood,
222 but also with a set of open questions to test in future research (see Box 3).

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232 **References**

- 233 1. Baumeister, R. F., & Bushman, B. J. (2014). *Social Psychology and Human Nature* (3rd
234 Edition). Belmont, CA: Wadsworth/ Cengage.
- 235 2. Kubota, J. T., Banaji, M. R., Phelps, E. A. (2012). The neuroscience of race. *Nature*
236 *Neuroscience*, 15(7), 940-8.
- 237 3. Avenanti, A., Sirigu, A., & Aglioti, S.M. (2010). Racial bias reduces empathic sensorimotor
238 resonance with other-race pain. *Current Biology*, 20, 1018–1022.
- 239 4. Gutsell, J. N., & Inzlicht, M. (2010). Empathy constrained: Prejudice predicts reduced
240 mental simulation of actions during observation of outgroups. *Journal of Experimental*
241 *Social Psychology*, 46(5), 841-845.
- 242 5. Serino, A., Giovagnoli, G., & Làdavas, E. (2009). I Feel what You Feel if You Are Similar
243 to Me. *PLoS ONE*, 4(3), e4930.
- 244 6. Xu, X., Zuo, X., Wang, X., & Han, S. (2009). Do you feel my pain? Racial group
245 membership modulates empathic neural responses. *The Journal of Neuroscience*, 29(26),
246 8525–8529.
- 247 7. Gallese, V., Keysers, C., & Rizzolatti, G. (2004). A unifying view of the basis of social
248 cognition. *Trends in Cognitive Sciences*, 8(9), 396-403.
- 249 8. Desy, M. C., & Theoret, H. (2007). Modulation of motor cortex excitability by physical
250 similarity with an observed hand action. *PLoS ONE*, 2(10), e971.
- 251 9. Maister, L., Sebanz, N., Knoblich G., & Tsakiris, M. (2013) Experiencing ownership over a
252 dark-skinned body reduces implicit racial bias. *Cognition*, 128 (2), 170-178.
- 253 10. Peck, T. C., Seinfeld, S., Aglioti, S. M., & Slater, M. (2013) Putting yourself in the skin of
254 a black avatar reduces implicit racial bias. *Consciousness and Cognition*. 22(3), 779-87.
- 255 11. Banakou, D., Groten, R., Slater, M. (2013). Illusory ownership of a virtual child body
256 causes overestimation of object sizes and implicit attitude changes. *Proceedings of the*
257 *National Academy of Sciences*, 110(31), 12846-51.
- 258 12. Farmer, H., Maister L., & Tsakiris, M. (2014). Change my body, change my mind: the
259 effects of illusory ownership of an outgroup hand on implicit attitudes towards that
260 outgroup. *Frontiers in Psychology: Cognitive Science*, 4, 1016.
- 261 13. Farmer, H., Tajadura-Jiménez, A., & Tsakiris M. (2012). Beyond the colour of my skin:
262 How skin colour affects the sense of body-ownership. *Consciousness and Cognition*, 21,
263 1242-56
- 264 14. Fini, C., Cardini, F., Tajadura-Jimenez, A., Serino, A. & Tsakiris, M. (2013) “Embodying
265 an outgroup: the role of racial bias and the effect of multisensory processing in
266 somatosensory remapping” *Frontiers in Behavioral Neuroscience*, 7,165.
- 267 15. Greenwald, A. G., McGhee, D. E., & Schwartz, J. K. L. (1998). Measuring individual
268 differences in implicit cognition: The Implicit Association Test. *Journal of Personality and*
269 *Social Psychology*, 74, 1464–1480.

- 270 16. Tsakiris, M. (2010). My body in the brain: A neurocognitive model of body-ownership.
271 *Neuropsychologia*, 48, 703-12.
- 272 17. Keysers, C., & Gazzola, V. (2009). Expanding the mirror: Vicarious activity for actions,
273 emotions, and sensations. *Current opinion in neurobiology*, 19(6), 666-671.
- 274 18. Brozzoli, C., Gentile, G., Bergouignan, L., & Ehrsson, H. H. (2013). A shared
275 representation of the space near oneself and others in the human premotor cortex. *Current*
276 *Biology*, 23(18), 1764-1768.
- 277 19. Iacoboni, M., Molnar-Szakacs, I., Gallese, V., Buccino, G., Mazziotta, J. C., & Rizzolatti,
278 G. (2005). Grasping the intentions of others with one's own mirror neuron system. *PLoS*
279 *biology*, 3(3), e79.
- 280 20. Morrison, I., Lloyd, D., Di Pellegrino, G., & Roberts, N. (2004). Vicarious responses to
281 pain in anterior cingulate cortex: is empathy a multisensory issue? *Cognitive, Affective &*
282 *Behavioral Neuroscience*, 4(2), 270-278.
- 283 21. Heberlein, A. S., & Atkinson, A. P. (2009). Neuroscientific evidence for simulation and
284 shared substrates in emotion recognition: Beyond faces. *Emotion Review*, 1(2), 162-177.
- 285 22. Botvinick, M., & Cohen, J. (1998). Rubber hands' feel'touch that eyes see. *Nature*,
286 391(6669), 756-756.
- 287 23. Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: perceptual illusion of body
288 swapping. *PloS one*, 3(12), e3832.
- 289 24. Lenggenhager, B., Tadi, T., Metzinger, T., & Blanke, O. (2007). Video ergo sum:
290 manipulating bodily self-consciousness. *Science*, 317(5841), 1096-1099.
- 291 25. Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person
292 experience of body transfer in virtual reality. *PloS one*, 5(5), e10564.
- 293 26. Tsakiris, M. (2008). Looking for myself: current multisensory input alters self-face
294 recognition. *PloS one*, 3(12), e4040.
- 295 27. Longo, M. R., Schuur, F., Kammers, M.P., Tsakiris, M., & Haggard, P. (2009) Self
296 awareness and the body image. *Acta Psychologica*, 132(2), 166-172.
- 297 28. Bufalari, I. et al. (2014) Enfacing others but only if they are nice to you. *Front. Behav.*
298 *Neurosci.* 8, 102
- 299 29. Kilteni, K., Bergstrom, I., and Slater, M. (2013). Drumming in immersive virtual reality:
300 the body shapes the way we play. *IEEE transactions on visualization and computer graphics*
301 19, 597-605.
- 302 30. van der Hoort, B., Guterstam, A., & Ehrsson, H. H. (2011). Being Barbie: the size of one's
303 own body determines the perceived size of the world. *PLoS One*, 6(5), e20195.
- 304 31. Preston, C., & Ehrsson, H. H. (2014). Illusory Changes in Body Size Modulate Body
305 Satisfaction in a Way That Is Related to Non-Clinical Eating Disorder
306 Psychopathology. *PloS one*, 9(1), e85773.

- 307 32. Normand, J.M., Giannopoulos, E., Spanlang, B., and Slater, M. (2011). Multisensory
308 Stimulation Can Induce an Illusion of Larger Belly Size in Immersive Virtual Reality. *PLoS*
309 *ONE* 6, e16128.
- 310 33. Paladino, M. P., Mazzurega, M., Pavani, F., & Schubert, T. W. (2010). Synchronous
311 multisensory stimulation blurs self-other boundaries. *Psychological Science*, 21(9), 1202-
312 1207.
- 313 34. Maister, L., Tsiakkas, E., & Tsakiris, M. (2013). I feel your fear: shared touch between
314 faces facilitates recognition of fearful facial expressions. *Emotion*, 13(1), 7-13.
- 315 35. Sforza, A., Bufalari, I., Haggard, P., & Aglioti, S. M. (2010). My face in yours: Visuo-
316 tactile facial stimulation influences sense of identity. *Social neuroscience*, 5(2), 148-162.
- 317 36. Tajadura-Jiménez, A., Grehl, S., & Tsakiris, M. (2012). The other in me: interpersonal
318 multisensory stimulation changes the mental representation of the self. *PloS one*, 7(7),
319 e40682.
- 320 37. Tao, R., Zhang, S., Li, Q., & Geng, H. (2012). Modulation of self-esteem in self-and other-
321 evaluations primed by subliminal and supraliminal faces. *PloS one*, 7(10), e47103.
- 322 38. Ma, Y., & Han, S. (2010). Why we respond faster to the self than to others? An implicit
323 positive association theory of self-advantage during implicit face recognition. *Journal of*
324 *Experimental Psychology: Human Perception and Performance*, 36(3), 619.
- 325 39. Field, A. P., & Davey, G. C. (1999). Reevaluating evaluative conditioning: A
326 nonassociative explanation of conditioning effects in the visual evaluative conditioning
327 paradigm. *Journal of Experimental Psychology: Animal Behavior Processes*, 25(2), 211.
- 328 40. De Houwer, J., Thomas, S., & Baeyens, F. (2001). Association learning of likes and
329 dislikes: A review of 25 years of research on human evaluative conditioning. *Psychological*
330 *bulletin*, 127(6), 853.
- 331 41. Gawronski, B., & Quinn, K. A. (2013). Guilty by mere similarity: Assimilative effects of
332 facial resemblance on automatic evaluation. *Journal of Experimental Social Psychology*,
333 49(1), 120-125.
- 334 42. Verosky, S. C., & Todorov, A. (2010). Generalization of affective learning about faces to
335 perceptually similar faces. *Psychological Science*, 21(6), 779-785.
- 336 43. Joy-Gaba, J. A., & Nosek, B. A. (2010). The surprisingly limited malleability of implicit
337 racial evaluations. *Social Psychology*, 41(3), 137-146.
- 338 44. Devine, P. G., Forscher, P. S., Austin, A. J., & Cox, W. T. (2012). Long-term reduction in
339 implicit race bias: A prejudice habit-breaking intervention. *Journal of experimental social*
340 *psychology*, 48(6), 1267-1278.
- 341 45. Gallagher, S. (2000). Philosophical conceptions of the self: implications for cognitive
342 science. *Trends in Cognitive Sciences*, 4, 14–21.
- 343 46. Baumeister RF. The self. In: Gilbert DT, Fiske ST, Lindzey G, editors. *The Handbook of*
344 *Social Psychology*. 4th Boston, MA: McGraw-Hill; 1998. pp. 680–740.

- 345 47. Tsakiris, M., & Haggard, P. (2005). The rubber hand illusion revisited: visuotactile
346 integration and self-attribution. *Journal of Experimental Psychology: Human Perception*
347 *and Performance*, 31(1), 80.
- 348 48. Ehrsson HH, Weich K, Weiskopf N, Dolan RJ and Passingham RE. Threatening a rubber
349 hand that you feel is yours elicits a cortical anxiety response. *Proc. Natl. Acad. Sci. USA*
350 (2007), 104, 9828-9833.
- 351 49. Slater, M., Perez-Marcos, D., Ehrsson, H. H., & Sanchez-Vives, M. V. (2008). Towards a
352 digital body: the virtual arm illusion. *Frontiers in human neuroscience*, 2,6.
- 353 50. Sanchez-Vives, M. V., Spanlang, B., Frisoli, A., Bergamasco, M., & Slater, M. (2010).
354 Virtual hand illusion induced by visuomotor correlations. *PloS one*, 5(4), e10381.
- 355 51. Kilteni, K., Normand, J. M., Sanchez-Vives, M. V., & Slater, M. (2012). Extending body
356 space in immersive virtual reality: a very long arm illusion. *PloS one*, 7(7), e40867.
- 357 52. Perez-Marcos, D., Sanchez-Vives, M. V., & Slater, M. (2012). Is my hand connected to my
358 body? The impact of body continuity and arm alignment on the virtual hand
359 illusion. *Cognitive Neurodynamics*, 6(4), 295-305.
- 360 53. Tajadura-Jiménez, A., Longo, M. R., Coleman, R., & Tsakiris, M. (2012). The person in the
361 mirror: using the enfacement illusion to investigate the experiential structure of self-
362 identification. *Consciousness and cognition*, 21(4), 1725-1738.
- 363 54. Slater, M., and Sanchez-Vives, M.V. (2014). Transcending the Self in Immersive Virtual
364 Reality. *IEEE Computer* 47, 24-30.
- 365 55. Apps, M. A., & Tsakiris, M. (2014). The free-energy self: a predictive coding account of
366 self-recognition. *Neuroscience & Biobehavioral Reviews*, 41, 85-97.
- 367 56. Seth, A.K. (2013). Interoceptive inference, emotion, and the embodied self. *Trends in*
368 *Cognitive Sciences*, 17(11), 656-663.
- 369 57. Moutoussis, M., Fearon, P., El-Deredy, W., Dolan, R. J., & Friston, K. J. (2014). Bayesian
370 inferences about the self (and others): a review. *Consciousness and cognition*, 25, 67-76.
- 371

372 **Glossary**

373 *Bodily resonance*: The process by which the perception of bodily states in others can activate
374 similar bodily states in the self [5,17,18]. This process is thought to be central to a number of
375 fundamental social processes including empathy, action understanding and emotion recognition.
376 This can be measured at the neural level, for example by recording activity in the premotor cortex
377 when observing other-performed actions [17], or behaviourally, for example by measuring the
378 increase in a participant's tactile sensitivity caused by observing another being touched [5].

379 *Body ownership*: Body ownership refers to the special perceptual status of one's own body,
380 which makes bodily sensations seem unique to oneself, that is, the feeling that "my body" belongs
381 to me, and is ever present in my mental life [16,45].

382 *Implicit association task (IAT)*: The IAT is a computerised task which involves a rapid
383 categorisation of verbal stimuli, pictorial stimuli, or both. Analysis of the patterns of response times
384 and errors provides a metric of implicit associations between categories. Commonly, the
385 associations measured are between a social category, e.g., a specific racial group, and positive
386 versus negative associations, to provide a measure of bias in implicit evaluative attitudes. Implicit
387 biases measured using this method have been found to be internally consistent, reliable and
388 predictive of explicit behaviours [15].

389 *Self-concept*: A multidimensional construct, comprising a collection of knowledge structures
390 regarding one's attitudes, dispositions, skills and abilities, which are temporally stable and trans-
391 situational [46].

392 **Box 1: Manipulations of Body Ownership**

393 *Rubber Hand Illusion (RHI)*

394 Watching a rubber hand being stroked synchronously with one's own unseen hand causes
395 the rubber hand to be attributed to one's own body, to "feel like it's my hand" [22]. This
396 synchronous stimulation not only elicits a subjective experience of ownership over the hand, but
397 also causes the perceived location of one's own hand to drift towards the rubber hand [47] and a
398 stress-evoked skin conductance response to be elicited when the rubber hand is threatened [48]. The
399 illusion of ownership over the rubber hand does not occur when the rubber hand is stroked
400 asynchronously with respect to the subject's own hand, and thus experiments investigating body
401 ownership commonly use asynchronous stimulation as a control condition. An illusion of the same
402 intensity can be also developed over a virtual hand by either synchronous visuotactile [49] or
403 visuomotor [50] correlations. This illusion persists through radical transformations such as
404 extensive elongation of the arm [51] or change in the virtual hand position [52] with respect to the
405 real one.

406 *Enfacement Illusion*

407 The enfacement illusion is a facial analogue of the rubber hand illusion. Participants watch a
408 video showing the face of an unfamiliar other being stroked with a cotton bud on the cheek, while
409 the participant receives identical stroking on their own, congruent cheek in synchrony with the
410 touch they see. As in the RHI, synchronous, but not asynchronous, visuotactile stimulation elicits
411 illusory feelings of ownership over the other's face [53]. Enfacement also influences social
412 cognition [33,34] and produces a measurable bias in self-face recognition, whereby participants
413 perceive the other's face as looking more like their own [26,35,36].

414 *Full-body illusions*

415 Illusory ownership over a physical manikin body that substituted the participant's real body
416 was demonstrated in [23]. Live video, from cameras attached to the manikin, was streamed to head-

417 mounted displays on the participants, so that when looking down they would see the manikin body
418 visually substituting their own. Synchronous tapping on the manikin body and the real body led to
419 illusory body ownership, in a similar way to the more traditional rubber hand and enfacement
420 illusions. More advanced systems have now been developed, using Immersive Virtual Reality (IVR)
421 [25]. Participants wear a head-tracked stereo head-mounted display which provides computer
422 generated images immersing the participant in a virtual world. The participant's own body is
423 substituted by a virtual body, viewed from a first-person perspective, with a motion capture system
424 so that their virtual body moves with their real body movements. This set up results in sensorimotor
425 correlations (visual, proprioceptive, tactile and motor) that elicit illusions of ownership and agency
426 over the virtual body [10,11,54].

427 **Figure 1. Inducing ownership over a body of another race**

428 A. *The Rubber Hand Illusion*: Light-skinned Caucasian participants observe a dark-skinned rubber
429 hand being stimulated in synchrony with their own unseen hand. This elicits a shift of body
430 ownership to incorporate the other-race limb [adapted from 9].

431 B. *The Enfacement Illusion*: Participants viewed the face of a racial outgroup member being
432 stimulated in synchrony with their own to induce a sense of ownership over the observed face [see
433 14].

434 C. *Immersive Virtual Reality*: (i) A participant wears a wide field-of-view stereo head-tracked head-
435 mounted display and a motion capture suit for real time body tracking. (ii) This is the participant's
436 view of the situation, whereby she can see her virtual body both directly and reflected in the mirror,
437 in stereo as shown. The body she sees could be dark-skinned, light-skinned or purple; in this case,
438 the virtual body is dark-skinned whereas she is light-skinned [adapted from 10].

439

440 **Figure 2: Changes in implicit racial attitudes after incorporating an other-race body in an**
441 **Immersive Virtual Reality setup**

442 Light-skinned Caucasian participants took part in a between-groups experiment where they
443 occupied a White (A) or Black (B) body in a virtual environment. They could see their body from a
444 first-person perspective when they looked down, as well as in a virtual mirror (see Figure 1, Panel
445 C(ii)). Two control groups were also included – in these conditions, participants either had no
446 virtual body (C), or the body was of an unnatural purple colour (D) to control for general
447 dissimilarity to their own skin. Participants' implicit racial biases were measured before and after
448 embodiment. Participants who embodied a Black avatar showed a decrease in their implicit biases
449 against Black individuals, which was significantly greater than for those who embodied a White
450 avatar. Adapted from [10].

451

452 Box 2: Predictive coding models of the Self

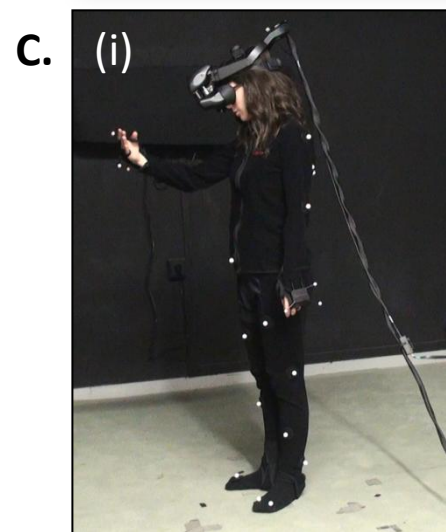
453 How we recognise ourselves, and what governs our sense of ownership over our bodies, is
454 still under much debate in the psychological and neuroscientific literature. However, a recent
455 interest in Predictive Coding as a unifying theory of brain function has provided a plausible
456 framework for understanding the cognitive basis of self-recognition [55]. On this account, one's
457 body is processed in a probabilistic manner as the most likely to be "me", given prior knowledge
458 about our bodies and incoming sensory information. Such probabilistic representation arises
459 through the integration of information from hierarchically organised unimodal systems in higher-
460 level multimodal areas. In the case of bodily illusions, viewing touch on a different body evokes a
461 sensation of touch on one's own body, and this generates bottom-up error signals from unimodal
462 sensory systems. Perceptual learning processes will update the body representation to first induce a
463 sense of ownership over the new body and next to incorporate perceptual features of the other's
464 body, in order to minimise this error and maintain a continual sense of 'mineness'. Therefore, this
465 account can explain how synchronous multisensory stimulation, such as that provided during the
466 Rubber Hand and other bodily illusions, can not only elicit fundamental shifts in body ownership,
467 but can also elicit a subsequent increase in perceived similarity between the bodies of self and other.

468 Importantly, the self is not represented solely at a basic, perceptual level. The self is a
469 multimodal, hierarchical construct containing both low-level, bodily representations as well as
470 higher level attitudes and beliefs. On a predictive coding account, these different levels of
471 representation continuously interact [55,56], as prediction errors, when left unexplained at one level
472 ,need to be processed and eliminated at a higher level of the hierarchy. An explanatory strength of
473 the predictive coding approach is that it can be applied to the whole information processing
474 hierarchy [e.g. 57], as it argues for complimentary hierarchical top-down and bottom-up processes.
475 A change in low-level, perceptual representations of one's own body in relation to the body of an
476 outgroup member creates errors further up in the processing hierarchy, as this new information now
477 conflicts with more abstract, higher-order representations of oneself and the outgroup. These errors

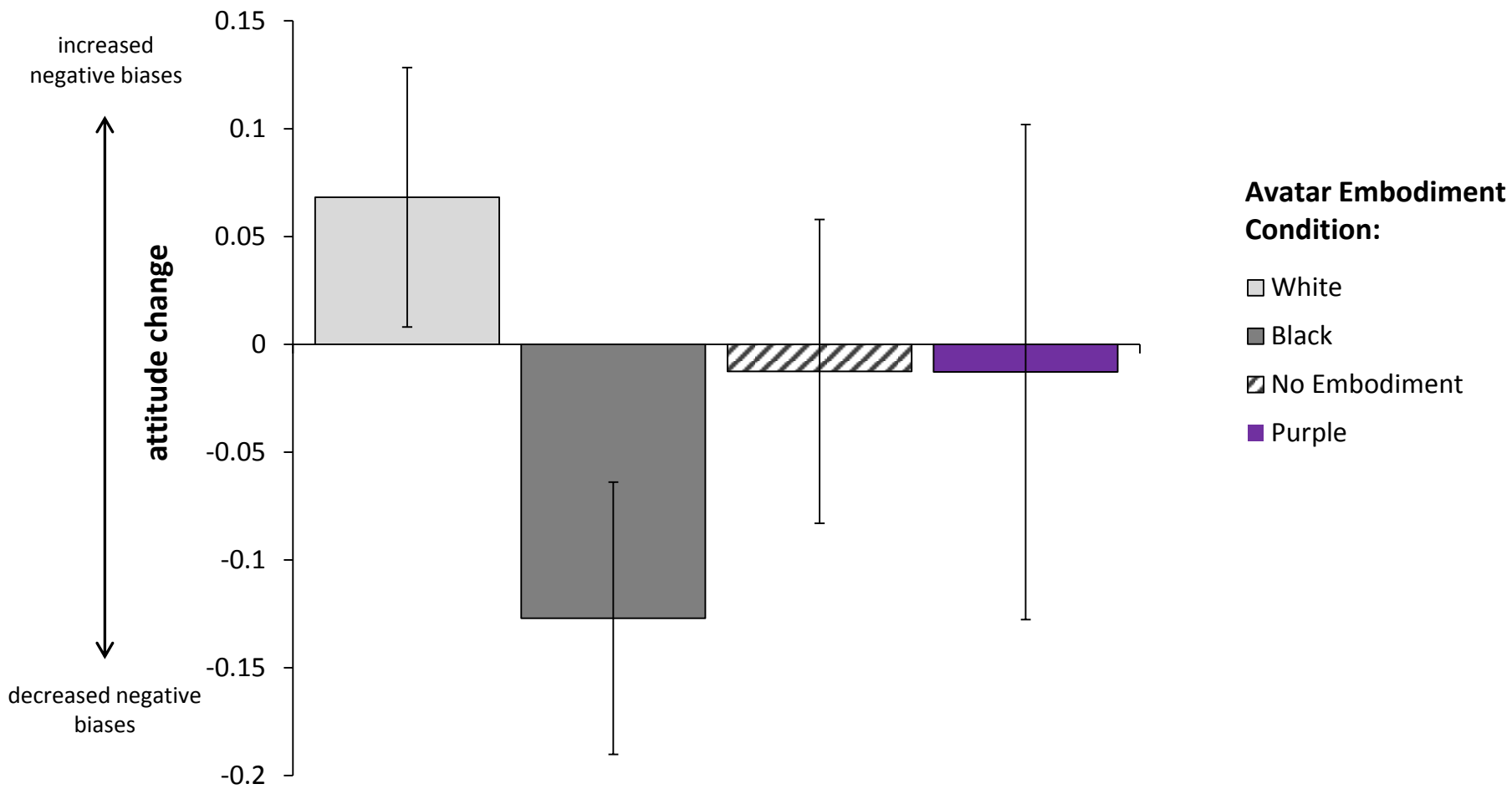
478 must then be minimised in a similar way, by updating attitudes and beliefs held about oneself and
479 the outgroup. In this way, the consistency within the multimodal self-representation is maintained.

480 **Box 3: Outstanding Questions**

- 481 • What is the time course of these effects? Are they persistent over time?
- 482 • What are the underlying neural mechanisms?
- 483 • Do these changes in implicit associations have behavioural consequences in daily life?
- 484 • Can similar effects be found with social groups that are not defined by perceptual
- 485 differences, such as political or religious groups, merely by informing the participant of the
- 486 embodied individual's group membership?



Figure



Tsakiris, Manos

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